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Lubrication

A Technical Publication Devoted to the Selection and Use of Lubricants

THIS ISSUE

Turbine Lubrication
Part II
Marine Turbines, Reduction Gears, and Lubricating Systems

The Effect of High Pressure on the Viscosity and Density of Lubricating Oils

PUBLISHED MONTHLY BY
THE TEXAS COMPANY

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Turbine Lubrication

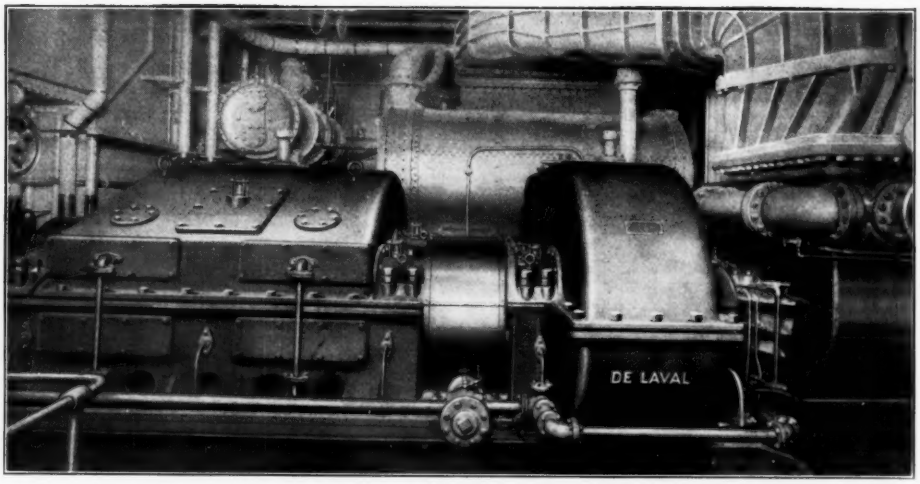
Part 2. Marine Turbines, Reduction Gears and Lubricating Systems

IN the February issue of LUBRICATION we took up the lubrication of steam turbines, paying particular attention to such conditions as exist in the majority number of cases in land stationary outfits. The principal feature discussed was the lubrication of bearings, and no attention was given to reduction gears and to the general lubricating system. In this article we shall take up the two latter features, particularly describing their connection with marine outfits.

In the large majority of stationary outfits on land, steam turbines are used to drive electrical generators from which the power is distributed to various operating machines about the plant or in neighboring plants. As previously stated the speed of the steam turbine must necessarily be high, but as an electric generator can easily be so designed that its speed conforms to that found most efficient for the turbine, it can be directly connected to the turbine. With marine outfits, however, it is impossible to design a propeller which will run economically at the high speed of the turbine. This is compromised in the case of some speed boats by running the turbine under speed and the propeller over speed. This procedure, however, is quite uneconomical. The problem then is to transmit the power generated by the turbine at high speed to the propeller which must rotate at comparatively low speed. Three methods, in general, have been used to carry out this transmission of power. First: the hydraulic; second: electrical, and third: the mechanical. (1) The hydraulic method utilizes a high speed pump upon the turbine shaft, and a low speed hydraulic turbine upon the propeller shaft. Several outfits have been constructed and operated on this principle, but even with the best designs the efficiency was found to be low and the method has not received general application. (2) The electrical drive is perhaps the most widely discussed method of power transmission on ships at the present time, and many very large ships have been successfully operated on this system. It consists, primarily, of a high speed generator directly connected to the turbine. The electrical power that is thus generated is utilized in driving a low speed motor connected to the propeller shaft. This system is quite elastic, but requires a large outlay in expense and much control apparatus. (3) At the present time the most generally used system of power transmission for ships is the mechanical drive using reduction geared apparatus.

Reduction Gears

Reduction gears used with turbine outfits may be either single or double. In the single reduction outfits a small pinion attached to the

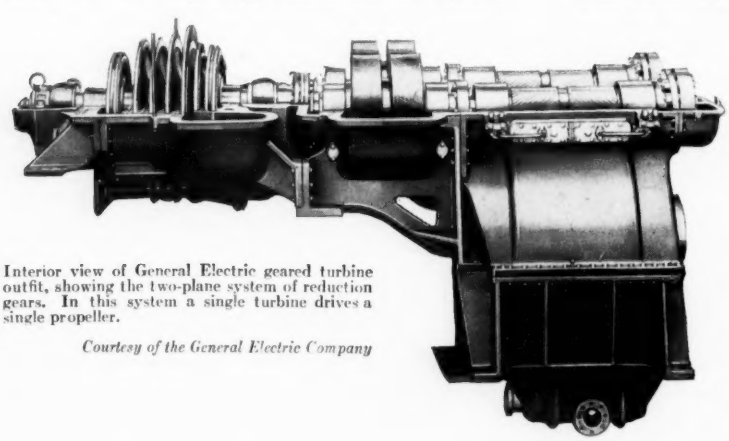


Engine room of a geared turbine driven ship

Courtesy of the De Laval Steam Turbine Co.

turbine shaft drives a large gear connected to the propeller shaft. In the double reduction gears the small pinion on the turbine drives a larger pinion on the counter-shaft to which is attached a smaller pinion which in turn drives a large gear on the propeller shaft. This latter system is applicable where large reduction speeds are required. A characteristic ratio of speeds used is 3,500 r. p. m. on the high speed shaft; 500 r. p. m. on the intermediate, and 100 r. p. m. on the low speed shaft. The gears used in this reduction apparatus are usually constructed with the herring-bone type of teeth to prevent end movement, though recently there has been some agitation for straight toothed gears.

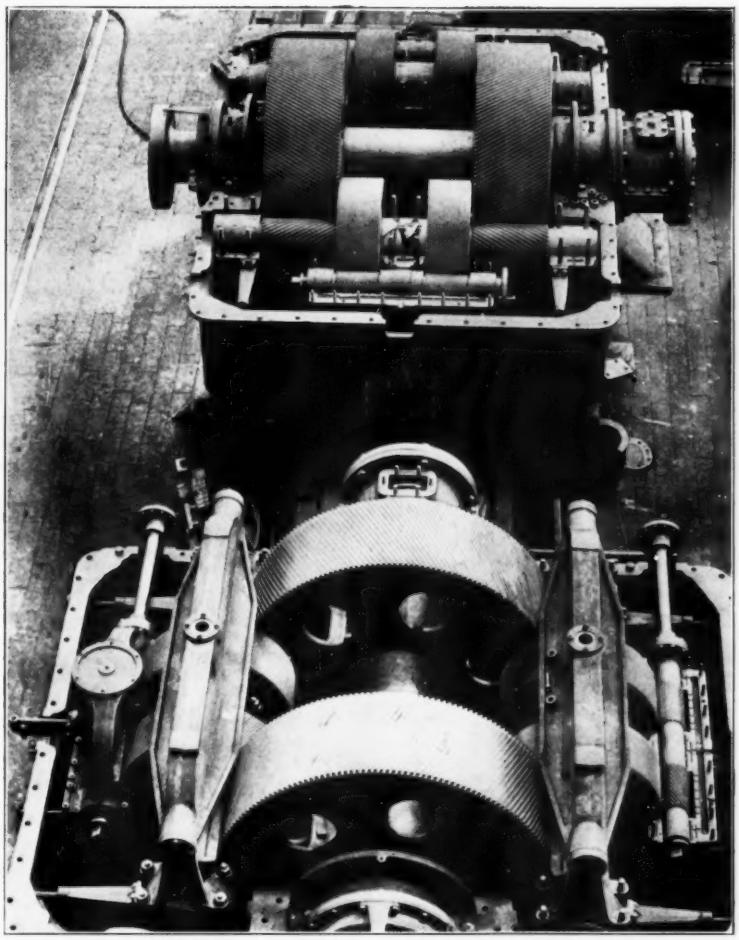
As the tooth clearances in reduction gears are very small, sometimes not over 1/1000 of an inch, the bearing supports must be rigid in order to eliminate changes in alignment due to heat expansions or binding stresses. The clearances in the bearing boxes also must be small and the same throughout, about 2/1000 inches, and the babbitted bearing pieces must be constructed with great accuracy in order that the system may run true with minimum binding. The lubrication of these bearings is the same as previously discussed under the main turbine bearings. It is sometimes thought advisable to install a more or less flexible coupling on the turbine shaft between the turbine proper and the small pinion of the reduction gear. This allows the gear to take its own alignment without undue strain, but this should be in the nature of an extra precaution and not a necessity. The alignment should be correct without the flexible coupling.



Interior view of General Electric geared turbine outfit, showing the two-plane system of reduction gears. In this system a single turbine drives a single propeller.

Courtesy of the General Electric Company

The use of reduction gears introduces a new problem in the lubricating system. These gears have excessively high tooth pressures running from 500–750 pounds per square inch, and in order to run smoothly and without wear should be lubricated. Too low a viscosity oil will not withstand these high pressures and will not prevent wear on the tooth surface. In any gear there is a slight slipping in the meshing action and the lubricant



Reduction gear outfit in which two high speed units are geared to one low speed propeller. Attention is called to the oil ducts adjacent to the small sized pinion. From these ducts oil is sprayed through fine holes or nozzles onto the pinion. Each set of gears has a set of these oil sprayers.

Courtesy of the Westinghouse Elec. & Mfg. Co.

should prevent or reduce the degree of metallic contact of these surfaces. It is generally considered desirable to supply a different lubricant to the gears from that supplied to the bearings, but in many cases this is found impractical and the gears are supplied from the same lubrication system as the bearings. This means that the oil used in the general system must be of sufficient viscosity at the temperature at which it is supplied to the gears to withstand the high tooth pressures and prevent wear. Oils of 300–500 seconds viscosity at 100° F. have been found to operate quite satisfactorily on the gears. On very slow running gears which normally have higher tooth pressures an oil with a viscosity of even higher than 500 seconds is often recommended.

But oils of these high viscosities will not operate satisfactorily in bearings, and therefore some compromise must be made to get the best all-round lubrication. As the viscosity of oils decreases with temperature rise, some operators reduce the viscosity of the oil for their bearings by heating that portion of the oil which goes to the bearings, while that which goes to the gears remains at normal temperature. If the temperature can be controlled this is a solution to the problem.

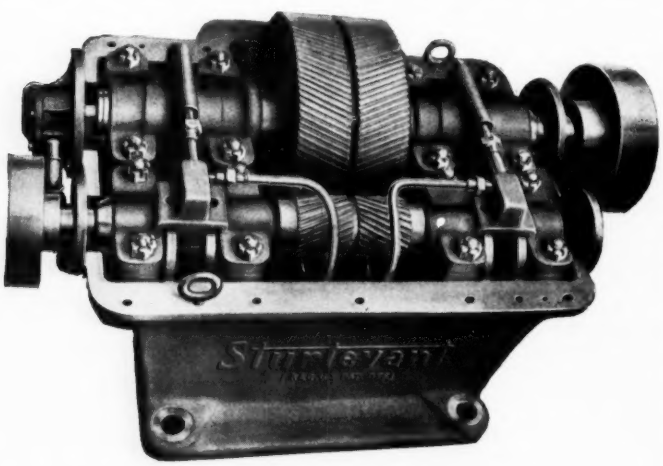
The oil is applied to the gears by means of a number of spray jets so arranged that the oil is forcibly played upon both the entrance and exit faces of the teeth as they mesh. The excess of oil is drained away to the oil sump.

There has been considerable discussion as to the cause of pitting of the gear teeth in reduction gear apparatus. For a while attempts were made to lay the blame upon the oil, but it is generally conceded now that the action is

due to the flaking off of small particles of metal due to the enormous tooth pressures. The action seems to take place on new apparatus and does not continue appreciably after a short time. Another trouble found in reduction gears is occasional rusting. This is no doubt due to the combined action of moisture and air in the oil, *i. e.*, emulsions, as in this form moisture and air are brought into intimate contact with the steel, and the possibilities of rusting are greatly accentuated. The remedy naturally is to use oil with a minimum tendency towards emulsion and to keep it in good condition by removing such emulsions as unavoidably occur.

Lubrication Systems

From the foregoing and the facts brought forth in the February issue of LUBRICATION, it is evident that steam turbines should be equipped with most efficient lubrication systems. Large quantities of oil are necessary which may become mixed with water or air, and due to the high temperatures may slowly change in structure. While this so-called breaking down takes place in only a very small proportion of the total oil used, it may be of such a nature as to affect the whole body of the oil and impair its lubricating qualities. Water, dirt, sludge, and gum due to the decomposition of the oil, therefore must be removed. This result can be accomplished in several ways and there are a number of systems designed for the purpose, which systems vary according to size and type of turbine, quantity of oil used and temperature and viscosity of oil required. Each system, however, must have a storage tank, a positive means for delivering oil to bearings, a means for cooling the oil to the required temperature, and some method of removing objectionable material. In small turbines the essentials are combined by allowing the oil to drain into a sump tank which is of ample capacity to allow the oil to remain in practical quiet sufficiently long for the sludge to settle out, which action will take place provided the oil was originally of the proper character. Unfortunately the sump tanks of many small turbines are of insufficient capacity to allow this settling to take place satisfactorily. It is usual to have cooling coils placed in this tank in order to reduce the temperature of the oil to that required for the bearings. In order not to disturb the sediment the oil is drained from the tank several inches above the bottom by means of a pump geared directly to the turbine shaft, and pumped to the bearings under pressure.



Single set of gears in which the oil is sprayed from the underside by means of the two curved pipes shown in the foreground. Spoon shaped nozzles on the end of these pipes throw a sheet of oil into the gears.

Courtesy of the B. F. Sturtevant Company

In larger turbine sets, more elaborate systems are used for reconditioning the oil, differing considerably in details but more or less the same in principle. In each of these systems there are storage tanks, sump tanks, cooling coils, strainers, filters, with the necessary pumps to carry the oil from one stage to another. Some systems in addition have special tanks where the oil can be heated, and thus expedite the settling out of the sludge. Whatever the type of system used it must be positive in action, as simple as practical to construct and contain sufficient safeguards to assure an adequate supply of oil at all times to the bearings and gears. This necessitates many parts being in duplicate and relief valves being placed so as to allow by-passing of the oil around strainers and filters if they become clogged.

Pressure and Gravity Systems

In order to force the oil through the lubricating train there are in general two systems—the

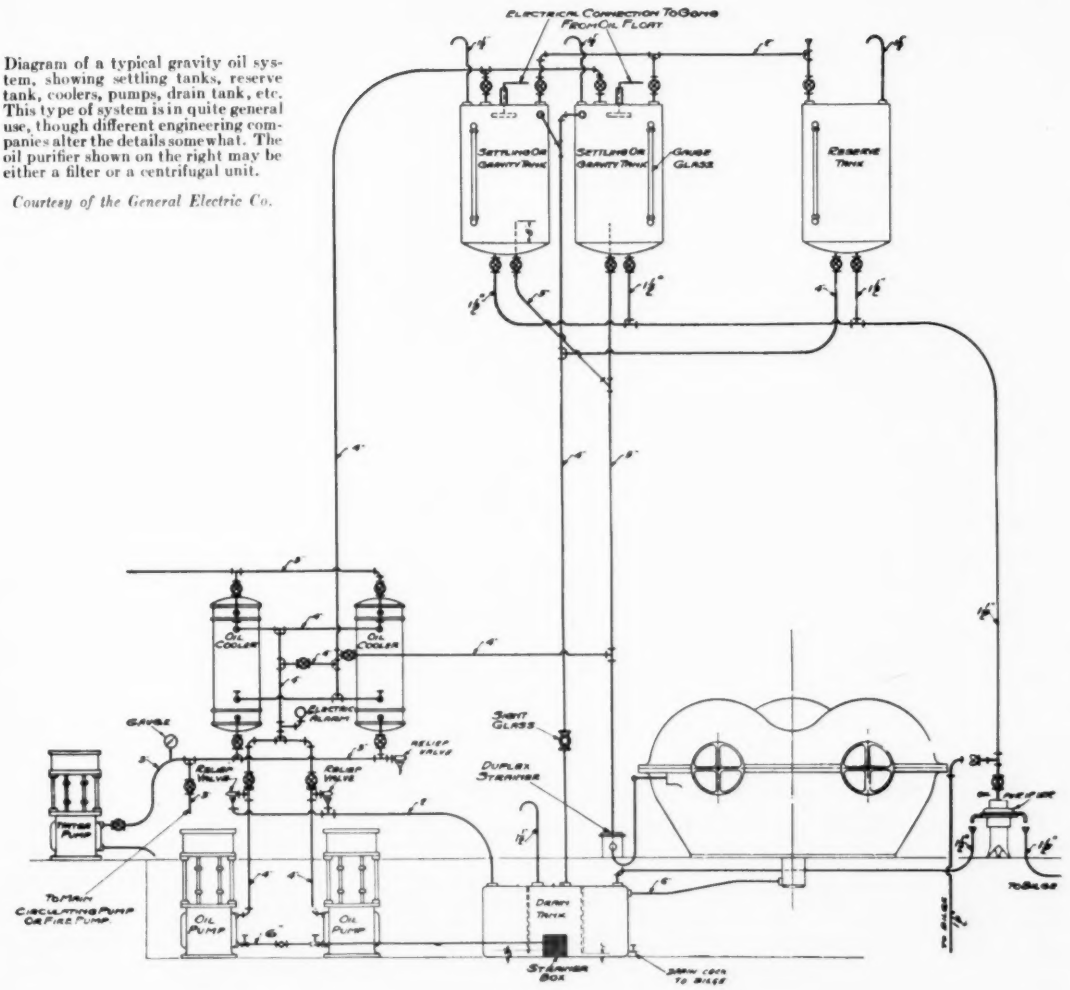


Diagram of a typical gravity oil system, showing settling tanks, reserve tank, coolers, pumps, drain tank, etc. This type of system is in quite general use, though different engineering companies alter the details somewhat. The oil purifier shown on the right may be either a filter or a centrifugal unit.

Courtesy of the General Electric Co.

pressure and the gravity. From the standpoint of first cost, the pressure system is the cheaper, due to the fact that less equipment is required, such as tanks, pipe, fittings, etc. In operating the pressure system, the lubricating oil pumps draw the oil from the sump or drain tank, or purifying system, and apply the oil to the unit under pressure, the oil draining back to the drain tank where it is again picked up by the pumps and again applied to the unit. This causes a continual circulation of the oil through the system. At the present time there are a number of units operating under the pressure system with approximately 400 gallons of lubricating oil in the system. This condition is usually wrong, as the circulation of the oil is so rapid that after coming in contact with heat conditions in passing over the bearings, it does not have time to settle and cool and will deteriorate very rapidly. In operating under the pressure system, it should be of ample size to handle from 800 to 1,000 gallons of oil in continuous circulation. The pressure system should pump oil to the bearings in excess of that required, a relief valve or other means being provided to drain the excess oil back to the sump tank.

The gravity lubricating system is handled somewhat differently from the pressure system. The oil is taken from the drain tank by the lubricating oil pumps, and delivered through the purifying system to a gravity tank located in the top of the engine room. From here the oil flows over the unit by gravity. The pressure obtained depends on the height at which the gravity tank is located above the unit.

It is often found desirable to have two tanks in the gravity system. This allows the oil sufficient time to settle and sludge and emulsion to be eliminated. It also provides a duplicate so that the tanks may be cleaned alternately.

A good volume of oil can be applied over the entire unit by either system, providing the systems are properly designed. With a pressure system, as long as the oil is applied to the bearings and gears at the proper point, there can be very little said in regard to improving this system. On some ships, as destroyers, it is necessary to use the pressure system as there is not room in which to place a gravity tank.

With the gravity system, improvement can be made over some of the present types of gravity tanks in use. There is one type of gravity system in which the lubricating oil pumps are controlled by a float in the tank, which automatically closes and opens the steam control on the throttle valve of the lubricating oil pump. By this method a high and low level of the oil is obtained in the gravity tank. When the high level is reached the float automatically closes the steam valve which slows down the lubricating oil pump and decreases the oil discharge from the pump. When the low level is reached, the float will automatically open up the steam valve and allow the lubricating oil pump to speed up, increasing the discharge of oil from the drain tank to the gravity tank. When operating under these conditions where lubricating oil pumps are governed by automatic control valves, a by-pass throttle valve should be installed for operation in case the automatic control valve becomes stuck from corrosion, or mechanical defects. The automatic control valve when installed should be equipped with union, or flange connections, and a valve on each side, so that the operator can make any necessary repairs in the shortest time and most convenient way.

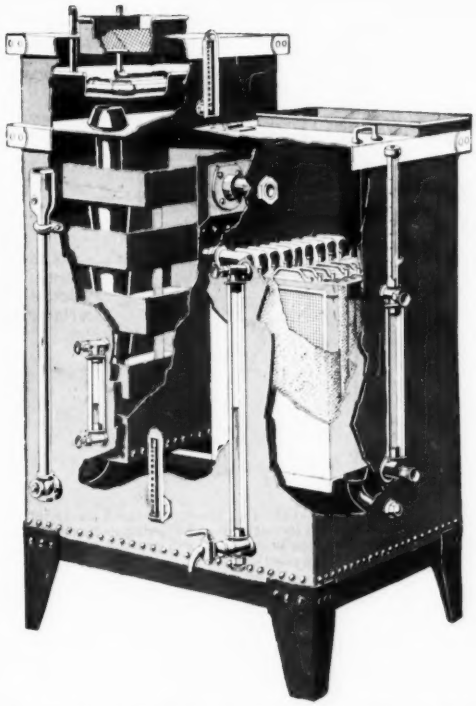
With this type of gravity system the oil is not agitated to the same extent as with the system where lubricating pumps are operating continuously at a set speed. This system also allows the oil to rid itself of any air that has accumulated which would cause a drop in pressure if an excessive air emulsion were formed. This emulsion takes place especially with some types of oil of high viscosity.

In some installations visible and audible alarms are used so as to indicate when the oil in the tanks is at its high and low levels.

The other type of gravity system is arranged the same as the above, with the exception that the pump works under the control of an automatic valve, so that it pumps continually at the same rate of speed after the system has been put in operation, working under steaming conditions. This causes the overflow from the gravity tank to drain tank to be operating at all times.

The lubricating oil system for marine practice should be a combination of both pressure and gravity types. This can be arranged by putting in a by-pass from the discharge side of the lubricating oil pumps to the main supply line from the gravity tank. With valves installed at the proper points either system can be operated independently.

The gravity tank should be of sufficient size to have at least four division plates with the discharge from the lubricating oil pumps striking a baffle plate installed in the first compartment. This will allow the force of the oil to be broken before it flows into the compartment, after which time the oil flows successively under the first division plate, over the top of the second, under the bottom of the third, and over the top of the fourth division plate into the last compartment. From here it flows into the main feed or supply line to the unit. The main supply line should be connected to the side of the gravity tank at least 6 inches from the bottom of the tank, in order that any sediment in the oil will have a tendency to settle at the bottom instead of flowing down the supply line and passing into the unit. All gravity tanks should be equipped as mentioned in order to eliminate the air from the oil as much as possible. Air will hasten oxidation, and quicken the rise in the viscosity of the oil. The gravity tank should be equipped with a vent pipe on each compartment to allow air to escape, as the cover on top of the tank is bolted down tight to prevent oil from escaping when the ship is rolling and pitching at sea. The tank should also be equipped with coils for heating the oil in cold weather, or at such time as the oils need reconditioning. An overflow line should be fitted to the last compartment approximately 6 to 8 inches from



Filtering unit in which the oil enters at the top, passes through a heating pan, thence to a series of settling pans, from which it overflows into the filter compartment. After passing through the filter cloths the clean oil is stored in the lower portion of the unit. The filtering units can be taken out separately and cleaned.

Courtesy of the Richardson-Phenix Company

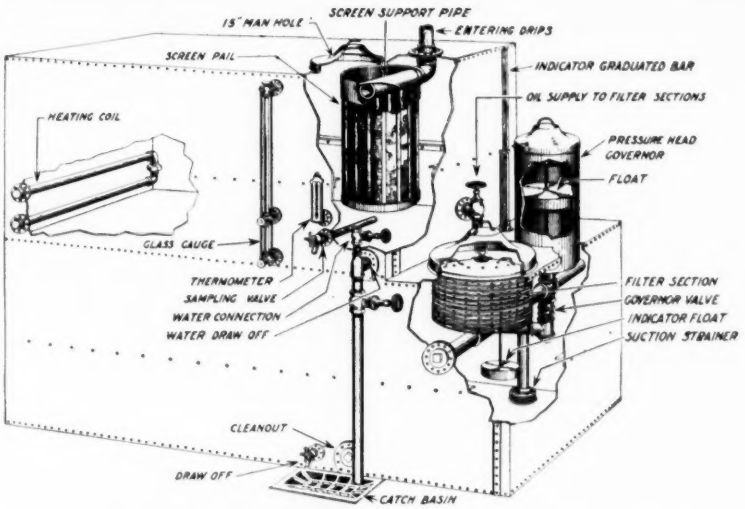
the top of the tank; this line leading back to the sump tank. At the lower engine room platform there should be installed in this line a sight glass which will enable the engineer to note the amount of oil in the system. On the last compartment of the gravity tank there should be fitted a sight glass equipped with automatic valves, so in case the glass becomes broken the pressure of the oil will close the valve. Each compartment should be equipped, at the lowest point, with a valve for the purpose of draining off water which may accumulate in this tank. This drain should be so installed that it will discharge into a funnel fitted on the drain line, which will lead to the bilge. The gravity tank should not be installed at an excessive height, as greater stress will be thrown on the oil pump in forcing the oil to the tank, while if the tank is too low, the proper pressure cannot be maintained for operating the gravity system. The proper height should range from 20 to 30 feet above the center line of the main unit. The tanks usually have a capacity of approximately 1,000 gallons. A float should be installed, electrically connected, that will ring an alarm bell to attract attention, should the oil level become low.

Pumps and Strainers

Lubricating oil pumps should be installed as low as practical in order that the oil either will flow to the pump or the vacuum lift will not be very great. These pumps should be installed in duplicate so that they may be used alternately, and should be of sufficient size as to be capable of handling a slight excess quantity of oil over that usually needed for proper lubrication. The pumps may be either of the rotary gear type or reciprocating, and may be direct connected to the unit or operate independently of it. The rotary pumps are simpler in operation, but if run at too high speed, they may churn the oil and form emulsions. This type of pump, driven by small steam turbines, has been found quite efficient, especially in large units. Reciprocating pumps may be either horizontal or vertical but the latter type, especially for marine use, is generally considered preferable. Many installations make provision for automatically governing the speed of the pump, instead of controlling it by direct connection to the turbine. In pump installations it is often found advisable to install a pressure gauge and a relief valve at the discharge side of the pump, so arranged that the excess oil is led back either to the sump tank or to the suction end of the pump. This is for the purpose of providing safety to the entire lubricating system, for should an excessive pressure develop the valve will open and relieve the pump of this pressure. In the case of reversing turbines, pumps are sometimes so equipped with check valves that they will operate in either direction. In all pump installations no soft or composition packing should be used, as under the action of the oil this packing may deteriorate and impair the quality of the lubricant.

In all lubrication systems there are installed strainers equipped with very fine mesh wire for eliminating any particles which may have accidently got into the system. These are usually installed on the discharge side of the oil pump and are in duplicate. Many systems of lubrication also have strainers installed in

other places. The strainers should have a large ratio of their area to that of the pipe—at least 6 to 1—and should require a low pressure head to overcome the friction of the oil through them. It is advisable to have strainers equipped with a relief valve or other means of overflow, so that if they become choked the flow of oil through the system will not be checked.



Filtering unit in which the oil enters through the pipe at the top, passes through a screen into a heating and settling compartment; from thence it passes through circular filtering sections into the clean oil compartment below. Only one filtering section is shown, but in practice it is usual to have a number of these, so that they may be cleaned in rotation.

Courtesy of the S. F. Bowser Company

Oil Coolers

In many lubricating systems of steam turbines, especially in the smaller units where there are no filtering systems, it is necessary that the oil which comes from the bearings and gears at a high temperature, should be cooled, so that it goes back to the bearings at the proper temperature. In many small units cooling coils are placed in the sump tank, but in the larger units it is generally found more practical to pass the oil through a separate cooling tank especially designed for the purpose. By this means cooling coils may be relieved of vibrations, and can be inspected more easily than if they were placed in the sump tank in the base of the unit. Oil coolers are generally built like steam condensers but must be equipped with baffle plates in order that the stream line flow of the viscous oil will be broken up, and the oil caused to come more completely in contact with the cooling surface. In oil coolers the pressure of the oil should be greater than that of the water so that in case of a leak, water will not be forced into the oil. It is advisable to pump the water through the cooler and not allow it to flow through by gravity, as this gives the engineer a more positive control of the water flow. Thermometers should be placed both in the inlet water line and the outlet oil line. In cold weather the oil cooler may often be by-passed.

Sump, Settling and Reserve Tanks

All lubricating systems are provided with sump tanks which are generally placed at the lowest point in the system, with the possible exception of the lubricating oil pump. In some systems the sump tank may act as a settling tank but generally the settling is done in a separate unit. The sump tank should be of ample capacity to contain approximately the entire quantity of oil used in the system, and should be equipped with vent pipes and float so that the amount of oil present can be noted by the engineer. A drain should be installed at the lowest point, and the suction line to the lubricating pump should take the oil from a point at least 2 inches above the bottom so that foreign particles will not be drawn into the system.

From the sump tank the oil is usually pumped to the settling tanks. These should be of ample size to hold the entire charge of oil in the lubricating system, and should be equipped with steam coils, drains, vent pipes, sight glasses, and various bypasses and cross-connections. By having the settling tanks large, the oil remains comparatively quiet, and if the oil is heated, water, emulsions and sludge will very largely separate out. Some engineers advise that sump and settling tanks be equipped with water legs so that the water and sludge which separate out will not be mixed with the mass of oil by the motion of the ship. Settling tanks may be installed in duplicate, which allows one tank to act as a

reserve in case the other is out of commission for cleaning or repairs. In many cases, however, it is considered advisable to have a special tank for the reserve oil.

Filters and Cleaners

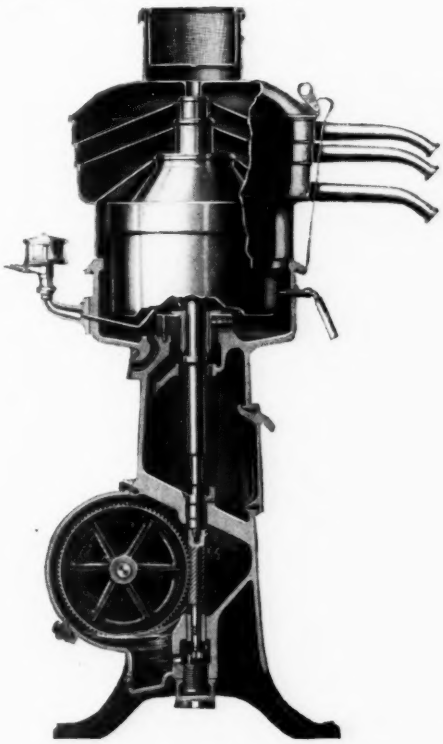
Most of the larger installations and many of the smaller ones in addition to the settling tanks provide filtering or cleaning units for reconditioning the oil and removing any harmful products of decomposition. In the filtering systems the oil is passed through cloths which remove such material as was not removed by the strainers and settling tanks. Filters are usually composed of a number of small units so arranged in a tank that they can be taken out one at a time and cleaned without disturbing the flow of oil through the filter. The settling tank and filter may be combined in one unit and in some cases, especially if a pressure system is used, the filter unit may also contain the supply tank.

Instead of filters many systems separate the oil from water and sludge by means of centrifugal units. As the impurities in the oil are generally heavier than the oil itself, they are thrown to the outside of the centrifuge and can be drawn off. These centrifuges are so designed that there is no loss of oil and even if the amount of water and sludge is very small, the oil cannot get into the drain line provided for the impurities.

It is not generally considered necessary to cause all the oil, as it comes from the turbine, to pass through the filtering or cleaning system on each cycle. In some systems a batch of oil is withdrawn at one time, treated and then returned to the system, while in others the pipes are so arranged that about 5% or 10% of the oil is continuously withdrawn, is passed through the filters or cleaners and then returned to the system. If the oil is of proper character to begin with, these partial systems are found to be quite efficient, and the oil is kept in service a long time by their use.

Piping

All piping should be so installed and equipped with valves that any of the duplicate units in the lubricating system can be by-passed or cross-connected if necessary or desirable. The oil filling line in the case of marine outfits should be fitted with a water-tight cap, and care should be taken that no other oil but turbine oil is admitted to this line, as any marine engine oil or cylinder oil becoming mixed with the turbine oil will so change its character that it will be unsuitable for turbine use, and may cause trouble throughout the system. Gauges, indicators, alarms, thermometers, etc. should be installed so that the engineer may know at any time the amount of oil in his supply tank, and also whether the pumps, strainers, and filters are operating efficiently or not. The piping should be installed with as few sharp bends as practical, especially on the line leading from the gravity tank or pressure pump to the bearings or gears. Gate valves are usually preferred to globe valves, as there is less loss in friction when the oil passes through them. In cleaning oiling systems waste should not be used as the fine lint, which it is impossible to prevent adhering to the surface, will clog the strainers and cause considerable trouble.



De Laval Separator

Centrifugal separator. The oil enters at the top through perforated screen which removes coarse particles. Sludge and water are thrown to the outside of the rotor. If the gravity of the oil is known the rotor can be so designed that nothing but sludge and water will be drawn off through the waste pipe.

Courtesy of the De Laval Separator Co.

Governors

The steam supply to many steam turbine outfits is controlled by means of oil operated governors and valves. The main steam valve is held in position by oil pressure on the two sides of a piston attached to the valve stem. The amount of oil on each side of the piston is controlled by the governor through inlet and outlet passages. The various systems of valve gear differ as to details in construction but all throttle the oil in its passage through the oil chamber of the valve in such manner as to control the quantity of oil on each side of the operating piston. The oil is usually furnished to the governors at a considerable higher pressure than should be used in the bearings or reduction gears, especially the former. Some installations take care of this by having a separate oil pump for the governor gear. Others use the same pump but pass the oil to the bearings through reducing valves. On account of the small passages incident to the throttling action, considerable care must be taken to keep the viscosity and consistency of the oil for the governors at a constant value. It is evident, therefore, that the temperature of the oil must not vary and that the oil must be free from emulsions and sludge; otherwise the governing action will be erratic. This again emphasizes the importance of removing all sludge and emulsions from the lubricating oil in order to have the turbine operate efficiently.

Summary and Conclusion

In the foregoing article we have discussed the operation of marine turbines, paying particular attention to reduction geared units, and have considered the lubrication of these units together with the necessary lubricating systems. In the February issue of LUBRICATION we considered the lubrication of the bearings of turbines, but the use of reduction gears greatly alters our lubricating problem. When gears are used it is advisable, if practical, to have them lubricated by a separate system from that used to distribute oil to the bearings, as the gears, on account of their high tooth pressure, require a much more viscous oil than do the bearings. This, however, is not the general practice, and most outfits compromise the situation by using the same oil on the gears as on the bearings.

With reduction geared units the same specifications as to refining, evaporation, flash point and acidity, apply, as outlined for bearings in the February edition of LUBRICATION, *i.e.*, it should be a highly refined mineral oil without the admixture of fatty oils, and should have a low evaporation loss, and practically no acidity. The question of viscosity and emulsion, however, should receive further consideration in the case of reduction geared units other than given for turbines without reduction gears. Most manufacturers of reduction gears require that the viscosity of the oil used on gears shall be 300″ Saybolt at 100° F. or higher, and in fact some gear manufacturers require that the viscosity shall be at least 500″ Saybolt at 100° F. As stated in the preceding article, the viscosity of the oil used in bearings should be about 180″ Saybolt at 100° F., though in some cases a lower viscosity can be used if all conditions are ideal. This lower viscosity desired for the best operation of bearings over that required for gears can easily be accomplished by allowing or causing 300″ or 500″ oil to operate at a higher temperature in bearings than would be required if 180″ oil were used. This might be considered a drawback if a great difference in temperature were required but such is not the case. Satisfactory turbine oils are made that have a large temperature coefficient, *i. e.*, that lower their viscosity rapidly with rising temperature. This fact allows a 300″ or 500″ oil to be used on bearings and yet necessitates only a rise of 10° to 25° F. in the bearing temperature over that which would normally exist if 180″ oil were used. This use of higher temperatures in bearings with high viscosity oils will not cause excessive evaporation losses or decomposition, for if properly refined, high viscosity oils do not evaporate or decompose as rapidly as low viscosity oils at the same temperature. As oil pressures, speeds, tooth pressures and general systems vary to such a large extent it is impractical to make a general recommendation as to what temperature is most suitable for bearings when lubricated from the same lubricating system as gears, and each system must be considered separately.

In marine outfits particular attention should be given to the separation of oil from salt water as well as fresh water, and as high viscosity oils separate more slowly from water than low viscosity oils, a slightly higher temperature should be maintained in the settling tank in order to obtain the best results. As stated in the February issue of LUBRICATION, no satisfactory emulsion test has as yet been devised which will definitely decide in the laboratory as to whether an oil will operate satisfactorily in turbines or not.

On account of the above, we must still depend upon the results obtained in practice to determine the suitability of a particular oil or class of oils for turbine use. This naturally makes it necessary to rely largely upon the integrity and past performances of the company marketing the oil, and of the engineers recommending the oil and the lubricating system.

The Effect of High Pressure on the Viscosity and Density of Lubricating Oils

SOME very interesting experiments in regard to the effects of high pressure on the density and viscosity of lubricating oils have been published recently by the Advisory Council of the British Department of Scientific and Industrial Research. No work of this nature was published before this, yet it is obviously important to know how much the viscosity of oil changes when subject to pressures such as occur in bearings. The compressibility of oils, in other words their change in density or gravity, is also of importance because of its connection between absolute and kinematic viscosities.*

The oils tested were typical of all classes of lubricating oils, containing the most important animal and vegetable oils as well as mineral oil distillates and cylinder stocks. For comparison, water was included also. The principal characteristics of most of these oils are given in table I on next page.

The apparatus used was very interesting and ingenious, but this article will be confined to the experimental results only. Readers who are interested in the apparatus and methods used are referred to the original report.

The data on compressibility of oils is shown in Fig. 1 in terms of changes of gravity or density with pressure, since density is the weight of a unit of volume, and compression changes the volume but not the weight. The compressibility of all the oils and of water shows much similarity both in magnitude and nature. They all show a general decrease of the rate of compressibility with increasing pressures, though the compressibility is very small. A pressure of 16,000 pounds per square inch causes but little over 5% compression or increase in specific gravity.

In Fig. 2 are shown the relative effects of pressure on viscosity, giving the percentage of increase of viscosity rather than its actual magnitude. It will be observed that as a class the "fatty" oils change less than mineral oils, but they change much more than does water. The value of these changes is best realized when looking over such a table as Table

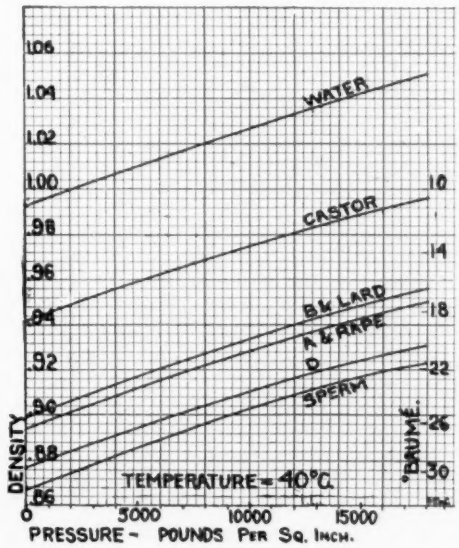


Figure I

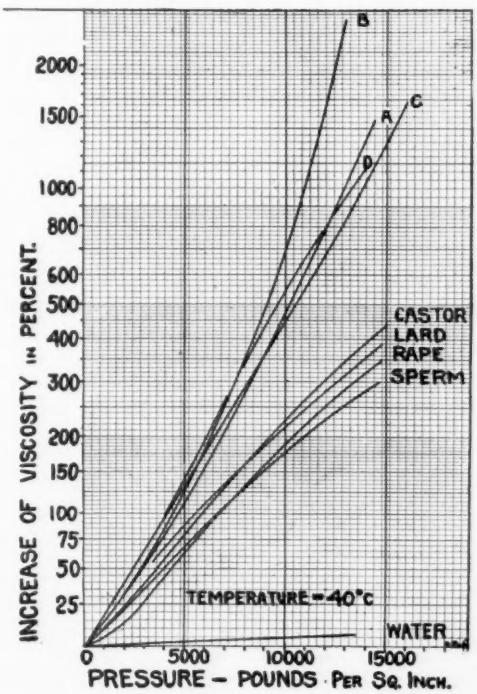


Figure II

* See "Viscosity," in Lubrication, July, 1920.

TABLE I

Oil	*Gravity Be at 60° F.*	*Flash† °F.*	*Pour °F.*	*Saybolt Viscosity at 100° F.*	*Surface Tension at 12° C.*	*Specific Heat at 20°C.*	*Dielectric Constant‡*
Castor	16.3	400	5	1250	37.6	0.508	4.62
Rape	23.5	405	10	270	36.6	0.488	3.06
Lard	23.5	353	10	240	38.3	0.483	3.10
Sperm	28.7	300	32	120	38.3	0.493	3.05
Mineral Oil A	24.2	395	37	390	34.3	...	2.36
Mineral Oil B	23.2	363	37	1140	35.5	...	2.37
Mineral Oil C	24.5	375	32	330	36.1	0.460	2.32
Mineral Oil D	27.0	500	42	2400	36.7	0.476	2.25
Water	10.0	...	32	29.5	72.5	0.998	...

† By Gray's apparatus, which is not a U. S. Standard.

‡ Ratio of oil to air—from observed capacity of a fixed air condenser of known value when immersed in the oil and subjected to a current of 500 cycles per second frequency.

II which shows pressures of such magnitude in many instances as to cause increases of viscosity in the neighborhood of 200 to 300%. It must be realized, of course, that this change of viscosity is not permanent, but exists only while the oil is subjected to pressure.

Column I of Table II, gives the data supplied from table No. 50 of Mark's Mechanical Engineer's Handbook—and is calculated as the total load on the bearing divided by its projected area. Beauchamp Tower has shown* that the actual pressure to which the oil film of a bath lubricated cylindrical bearing is subjected varies, as might be expected, from a minimum at points about 90 degrees from the direction of application of the load to a maximum at the center. In his investigation he drilled small holes in a bearing and connected them by means of tubes and suitable valves to a pressure gauge so that the oil pressures at these points could be read directly. From such readings, he calculated the total upward force of the oil film, and found it to be approximately equal to the load on the bearing, proving that the load was completely supported by the oil film. The maximum pressure was found to be about double the average as shown in Column I, and accordingly Column II has been added to show how great may be the pressures to which oil films are frequently subjected in cylindrical bearings in service. The oil films on gear teeth are subjected to still much higher pressures.

It is hard to say just how much influence this change of viscosity with pressure has on questions of lubrication and bearing friction, but it is certainly a subject worthy of further investigation, particularly when it is realized that different mineral oils may show such different relations between viscosity and pressure as are shown by the curves for oils A and B, of Fig. 2, when compared with oils C and D.

It is of real interest to know that pressure as well as temperature changes the viscosity of fluids, particularly of lubricating oils.

TABLE II

Class of Machine	*I Average Pressure on Bearing Lbs. per Sq. Inch*	*II Max. Pressure on Oil Film Lbs. per Sq. Inch*
Gas Engines:		
Main Bearings	500–700	1000–1400
Crank-pin Bearings	1500–1800	3000–3600
Cross-head-pin Bearings	1500–2000	3000–4000
U. S. Navy		
Main engine Bearings	275–400	550– 800
Main engine crank-pins	400–500	800–1000
Railroad Locomotives		
Cross-head-pin Bearings	3000–4000	6000–8000
Crank-pin Bearings	1700–1700	3000–3400
Driving-wheel-journal Bearings	Up to 556	–1112
Miscellaneous		
Bearings for slow speed and intermittent load, as for punch presses, shears, etc.	3000–4000	6000–8000
Bearings for very low speeds, as for turn tables and bridges	7000–9000	...

* Proc. Inst. M. E. January, 1885.

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Selecting an Oil for Reduction Geared Turbines

IN the reduction geared turbine there are two different lubricating requirements.

The same lubricating oil must serve the reduction gears as well as the bearings, but because there is one oiling system for both, obviously two different oils, one "light" for bearings and the other "heavy" for gears, cannot be used.

This problem is solved by the use of oils with a so-called steep viscosity characteristic curve.

These oils have the high viscosity necessary to lubricate the gears at the low temperatures under which they operate, and as they decrease in viscosity to a marked degree under the high temperature of the bearing system they adjust themselves quickly so as to take care of the lubrication of the bearings satisfactorily.

Thus by forcing cool oil (high viscosity) to the gears, and warm oil (low viscosity) to the bearings both conditions can be met with the same oil.

For these purposes we recommend TEXACO MARINE TURBINE OILS, which have the steep viscosity curve.

On the other hand, for direct connected turbines without reduction gears where bearings only have to be lubricated, an oil with a flat viscosity curve may be used.

Under these conditions the viscosity required is not usually high, and there need be only a comparatively small drop in the viscosity from that at room temperature to the temperature at the bearings.

In this case we recommend TEXACO REGAL OIL.

The Oils We Recommend for Geared Turbines Are:

TEXACO MARINE TURBINE OIL "M"
TEXACO MARINE TURBINE OIL "H"

[*The latter to be used on turbines having high pressure reduction gears such as the Falk type*]

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Here's some True Talk!

This actually occurred and it is so good that we want to pass it on as it happened

ONE DAY last week a man dropped in to see us on business. He picked up a little leaflet describing the Texaco Easy Pour Can while waiting to be shown into our office.

He came into our little sanctum and before broaching his regular business, said, 'Say, Mr. V., can't I have some of these shipped up to my summer place? Gosh, they're great! If I had known about them last year I would have saved a little repair bill of some Two Hundred Dollars.

Scenting a story, we asked him to be seated and give us the "How" and the "Why." He spoke as the newspaper reporters have it, "Substantially as follows":

"I have to tell you first that I have a little summer place up near Greenwood Lake and I drive into the city every week day, and when I drive, I drive! I seldom hit less than 30 miles, and I generally drive in by the back road to avoid traffic.

"I was rolling along one hot Monday morning, and could tell that a cylinder was missing. I looked at my indicator and saw it waving back and forth like this—the engine was nearly boiling over. I found I was short of oil.

"It just so happened that along this road there isn't a filling station or a garage for some seven miles and I had to keep on driving.

"After that my No. 5 cylinder leaked oil. It was badly burned, scored and carbonized.

"I had to lay up the car—and I have just heard the bad news from the repair man—Two Hundred and some odd Dollars! Just because I didn't have a little extra oil along.

"That's why I want some of these Texaco Easy Pour Cans. Can you arrange to ship about 10 of them?"

"We can do better than that"—we said—"We will send you a full case."

"How many is that?"

"Twenty two-quart cans to a case."

"That's fair enough! I'll use them up this summer. They are mighty fine things to have around.

"From now on I'll have one in my car always, and I can see where a stock of them in my little garage will come in mighty handy.

"Just as you say in your little folder, 'punch the seal and pour out the contents, and don't worry about stowing away a greasy can or an oily funnel'."

Thereupon we rang up the Sales Department, took his order for a case in the right grade for his car, and from now on our friend will be insured against motor trouble from this source, and he is always going to have good oil—TEXACO MOTOR OIL—when he needs it.

A 'phone call to our nearest office or station or a call on the dealer near you will give you the same comfort and protection. Buy the Texaco Easy Pour Can by the case.

TEXACO MOTOR OIL
Light, Medium, Heavy & Ex. Heavy in the Easy Pour Two Quart Can.

Patented by the Texas Company. Used only for Texaco Motor Oils.

Keep an Easy Pour Can in your car always. It stows away like a thermos bottle.

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